

Estimation of noise shielding by barriers

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Associated software: ESDUpac A7911
ESDUpac B7911
VIEWpac M7911



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ESTIMATION OF NOISE SHIELDING BY BARRIERS

1. NOTATION

		<i>Units</i>	
		<i>SI</i>	<i>British</i>
a	speed of sound	m/s	ft/s
$C(X), S(X)$	Fresnel integrals		
d	shortest distance from vertical plane through barrier edge	m	ft
F	$f(X_1) + f(X_2)$		
f	frequency	Hz	Hz
$f(X), g(X)$	auxiliary Fresnel functions		
G	$g(X_1) + g(X_2)$		
H	height above ground plane	m	ft
J	parameter in $\Gamma_2 = Jf^{1/2}$	s ^{1/2}	s ^{1/2}
j	number of routes being considered		
k	constant in $a = kT^{1/2}$	m/(s K ^{1/2})	ft/(s K ^{1/2})
L	total sound attenuation $L = L_1 + L_2 + L_3 - L_4$	dB	dB
L_1	sound attenuation due to diffraction round an edge	dB	dB
L_2	difference in source sound pressure levels due to angular characteristics of source	dB	dB
L_3	inverse square law correction	dB	dB
L_4	correction to L_1 at low values of shielding	dB	dB
l	shortest path via barrier edge between source and observer	m	ft
M_1	angular function of $\theta_o + \theta_s$, see Section 2.3.2		
M_2	angular function of $\theta_o - \theta_s$, see Section 2.3.2		
R	shortest distance through barrier between source and observer	m	ft
R_1	greater of r_s and r_o	m	ft

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R_2	lesser of r_s and r_o	m	ft
r, θ, z	cylindrical polar coordinates		
r^*	distance, see Sketch 2.2	m	ft
S	sound pressure level	dB [†]	dB [†]
S_D	free field sound pressure level radiating in direction of observer	dB [†]	dB [†]
S_E	free field sound pressure level radiating in direction of barrier's edge	dB [†]	dB [†]
T	temperature	K	K
X_1	argument in auxiliary Fresnel functions for $\theta_o + \theta_s$		
X_2	argument in auxiliary Fresnel functions for $\theta_o - \theta_s$		
x, y, z	Cartesian co-ordinates		
Z	non-dimensional lateral separation of source and observer ($Z = z_o - z_s /(r_o + r_s)$)		
β	wedge angle, see Sketch 2.4	deg	deg
$\Gamma, \Gamma_1, \Gamma_2$	distance parameters ($\Gamma = \Gamma_1 \Gamma_2$, see Equations (2.6) and (2.7))		
Γ_3	parameter given by $\Gamma_3 = \Gamma/f^{1/2}$	s ^{1/2}	s ^{1/2}
α	function of θ , see Section 3.2		
γ	angle between barrier face on observer's side and vertical plane through barrier edge, see Sketch 2.4	deg	deg
ε	angle dependent on θ and β given by $\varepsilon = \beta - \theta_s$	deg	deg
η_1, η_2	functions of θ and β , see Section 2.3.2	deg	deg
θ	angle between barrier and ray to observer or source, see Sketch 2.2	deg	deg
λ	wavelength ($\lambda = a/f$)	m	ft
ϕ	angle of incidence of ray onto barrier, see Sketch 2.2	deg	deg
ψ	angle into shadow, see Sketch 2.4	deg	deg

For footnotes refer to end of Notation Section

Suffixes

<i>b</i>	barrier
<i>i</i>	route identifier
<i>o</i>	observer
<i>s</i>	source

* The reference pressure for all decibels is $20\mu\text{ Pa}$ (0.0002 dyn/cm^2 or $4.177 \times 10^{-7}\text{ lbf/ft}^2$).

2. NOTES

2.1 General

When a barrier is placed between a sound source and an observer, sound reaches the observer by diffraction over the top of the barrier, or round the barrier edges, and by direct transmission through the barrier. In many practical cases the barrier is designed such that the transmission path is so highly attenuated that it may be neglected. Hence this Item is only concerned with the sound reaching the observer via the edge of the barrier, *i.e.* propagating along any of the paths SBO shown in Sketch 2.1. A method is provided for estimating the shielding effect of a barrier in terms of the difference in sound level received at a given location on the side of the barrier remote from the noise source and the sound level received at the same location without the barrier. The sound attenuation due to a barrier is therefore dependent on the redistribution of sound energy by diffraction over the top, and round the edges, of the barrier and the increased propagation losses which result from the change in the length and direction of the sound propagation path due to the presence of the barrier.

In the procedure used in this Item for estimating the loss due to diffraction it is assumed that the noise is emitted by a point source and that both the source and observer are at large distances from the diffracting edge relative to the wavelengths of the sound considered. Also it is assumed that barriers are rigid, wedge-shaped (as described below) and have hard surfaces and sharp edges. The theory breaks the attenuation due to diffraction into two parts, L_1 and L_4 . The expressions defining L_1 and L_4 are given in Appendix A, Section A.1. For attenuations greater than 10 dB L_4 is negligible. The wedge-shaped barrier can vary between an infinitesimally thin wall, where the wedge has become a surface. When $\beta = 270^\circ$ the barrier would represent a right-angled wedge which for example could be the corner of a building.

The increased sound propagation path length due to the presence of the barrier introduces additional attenuations due to increases in spherical spreading loss and atmospheric attenuation. Often these effects are very small and may be neglected in calculating shielding effects. However, in the case when both source and observer are close to the barrier the sound spreading loss, L_3 , may be significant and should be calculated using the inverse square law as described in Section 2.4.2. The effects of the atmosphere are discussed in Section 2.4.3 and, in the calculation of attenuation due to diffraction, a steady uniform atmosphere is assumed.

The attenuation due to diffraction is measured relative to the source level, S_E , propagating in the direction of the diffracting edge. For a directional source there will be an additional effect, L_2 , due to the different intensities of radiation along the directions of the direct path and the path via the edge of the barrier (see Section 2.4.1).

This Item provides a means of estimating the total attenuation at an observer position due to the presence of a barrier, interposed between the source and observer, relative to the free-field level when no barrier is present. The total attenuation L is given by

$$L = L_1 + L_2 + L_3 - L_4.$$

During any preliminary investigations into the attenuation by barriers, when the source characteristics are not known, it is usual to assume that $L_2 = 0$. However, in some cases source directivity patterns should be investigated before a barrier design is finalised.

The attenuation due to shielding is frequency dependent; as it increases slowly with frequency, the centre frequency of a frequency band should be used when estimating the attenuation for the band. When considering frequency weighted units, *e.g.* dBA, PNdB *etc.*, it is difficult to achieve levels of shielding greater than 20 dB although at high frequencies the attenuation at a frequency could be greater than 30 dB.

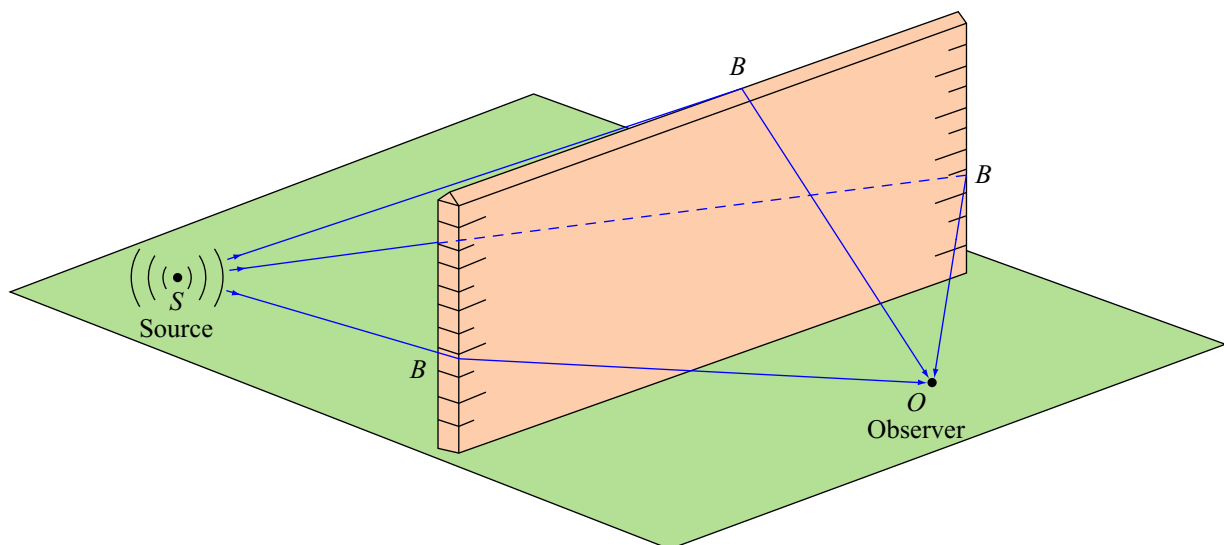
Appendix A gives a numerical method which enables the values of attenuation due to shielding to be calculated.

A computer program, known as ESDUpac A7911, is provided. This program offers the user the additional facility of adjusting spectra at one-third octave band centre frequencies for barrier attenuation. These spectra must be entered via the common input data file, see Appendices B and C. Implementation of the program is described in Appendix B.

2.2 Geometric Relationships

The geometric arrangement of source, observer and barrier is shown in Sketches 2.1, 2.2 and 2.3. For convenience the barrier is represented as a thin wall (*i.e.* $\beta = 360^\circ$).

Sketch 2.1 shows a practical example of a finite barrier with the source and observer on the opposite sides of the barrier and indicates the various propagation paths round and over the barrier which should be considered when estimating noise shielding.

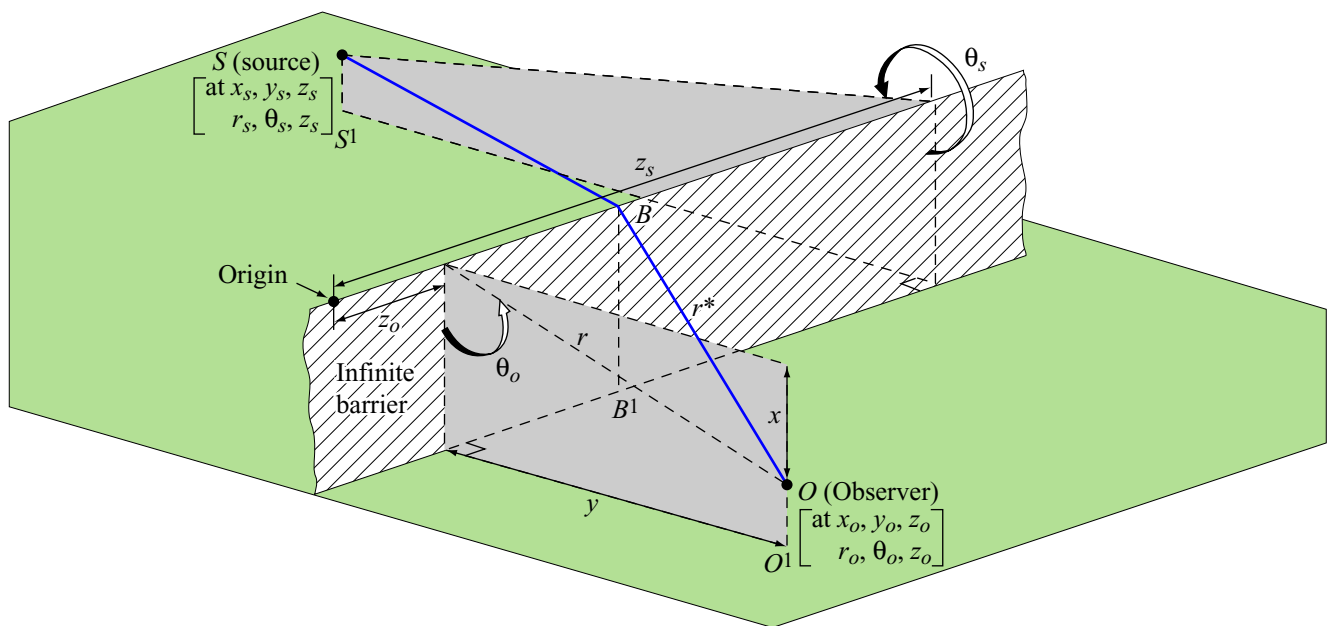


Sketch 2.1

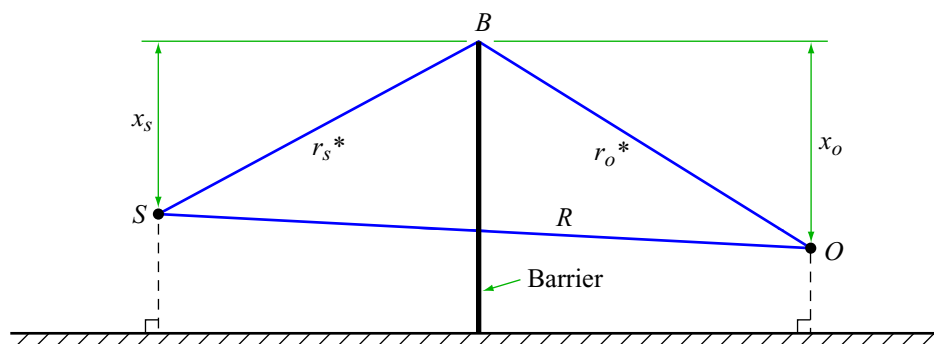
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The total attenuation of the barrier shown in Sketch 2.1 is given by the combination of the attenuations due to the propagation paths over the top and round the edges of the wall. The attenuation of sound by each propagation path is defined in terms of the minimum length of ray path via the barrier edge under consideration. In the method for estimating attenuation it is assumed that the barrier extends to infinity in the line of the diffracting edge being considered. In practice it is often only necessary to consider the edge giving the least sound attenuation as attenuations which are 10 dB more than the lowest can be neglected. A more complete discussion of finite barriers is given in Section 2.5.

Considering any one of the sound paths SBO, shown in Sketch 2.1, the problem is simplified by representing the barrier as an infinitely long barrier with the sound being diffracted by the top edge, as illustrated in Sketch 2.2. The diffracting edge of the barrier is located in the xz -plane with the edge at $x = 0$, stretching from $z = -\infty$ to $z = +\infty$.



Sketch 2.2 General arrangement



Sketch 2.3 (View on plane SBO)

The basic geometric relationships relating the position of the source, barrier and the observer are as follows.

The length, R , of the direct path, SO , is given by

$$R = [(x_o - x_s)^2 + (y_o - y_s)^2 + (z_o - z_s)^2]^{1/2}, \quad (2.1)$$

and the length of the path via the edge, SBO , is given by

$$l = [(r_o + r_s)^2 + (z_o - z_s)^2]^{1/2}, \quad (2.2)$$

where the conversion from Cartesian to cylindrical polar co-ordinates is made using the following relationships

$$x = r \cos \theta \quad (2.3)$$

$$y = r \sin \theta \quad (2.4)$$

and
$$r = [x^2 + y^2]^{1/2}. \quad (2.5)$$

2.3 Shielding Parameters

The effectiveness of a barrier depends on the geometric relationships relating the positions of the noise source, observer and the barrier. Shielding is evaluated using the four parameters defined in the following subsections.

2.3.1 Distance parameters

The distance parameter Γ_1 takes account of the relative distances of the source and observer from the barrier's edge and is given by

$$\Gamma_1 = \left[2 \frac{R_1}{l} \right]^{1/2}, \quad (2.6)$$

where R_1 is the greater of the source or observer distances from the barrier's edge.

The parameter Γ_2 is the acoustic scaling function and is given by

$$\Gamma_2 = \left[\frac{R_2}{\lambda} \right]^{1/2},$$

where R_2 is the lesser of the source or observer distances from the barrier's edge. It is convenient to express Γ_2 as

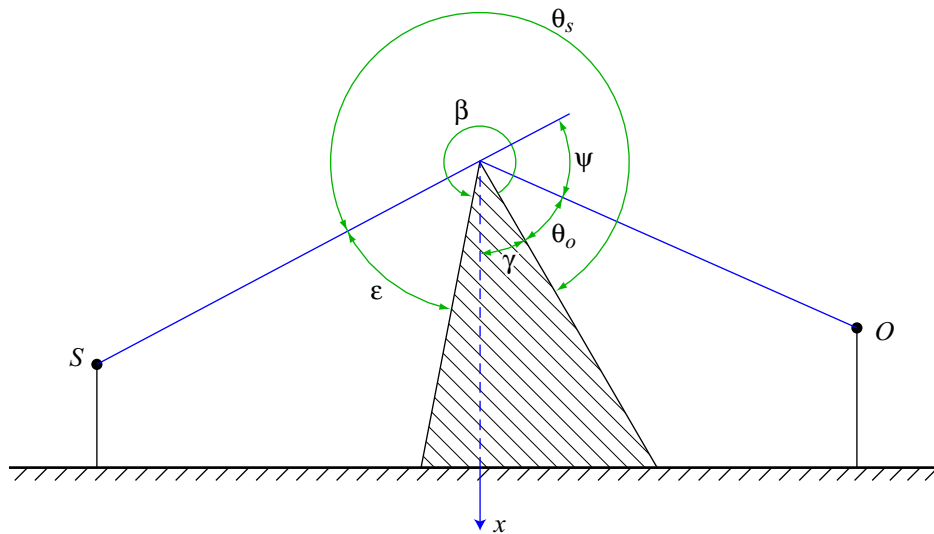
$$\Gamma_2 = Jf^{1/2}, \quad (2.7)$$

where
$$J = \left[\frac{R_2}{kT^{1/2}} \right]^{1/2}. \quad (2.8)$$

For air $k = 20.0468 \text{ m/(s K}^{1/2}\text{)}$ or $65.7703 \text{ ft/(s K}^{1/2}\text{)}$.

2.3.2 Angle dependent parameters

For clarity Sketches 2.1 to 2.3 are drawn for a thin flat barrier. The arrangement for a typical wedge-shaped barrier is illustrated in Sketch 2.4. The view in Sketch 2.4 is in the vertical plane normal to the barrier.



Sketch 2.4 General barrier shape (View normal to barrier)

The limiting cases for β are an infinitesimally thin vertical wall, where $\beta = 360^\circ$, and a flat surface, where $\beta = 180^\circ$.

The two angle dependent parameters M_1 and M_2 are functions of β and of $(\theta_o + \theta_s)$ and $(\theta_o - \theta_s)$ respectively. Expressions for these quantities are given in Appendix A, Section A.1.1.

The values of M_1 and M_2 are found from Figure 2, using the following angular values for η_1 and η_2 . For M_1 use η_1 where

$$\eta_1 = \theta_o + \theta_s \quad \text{when} \quad \theta_o + \theta_s \geq \beta$$

and
$$\eta_1 = 2\beta - (\theta_o + \theta_s) \quad \text{when} \quad \theta_o + \theta_s < \beta,$$

and for M_2 use η_2 where

$$\eta_2 = |\theta_o - \theta_s| \quad \text{when} \quad |\theta_o - \theta_s| \geq \beta$$

and
$$\eta_2 = 2\beta - |\theta_o - \theta_s| \quad \text{when} \quad |\theta_o - \theta_s| < \beta.$$

Since M_1 is a function of $(\theta_o + \theta_s)$ and $\theta_s = (\beta - \epsilon)$, the value of M_1 is dependent on the wedge angle and the angular symmetry of the source and observer with respect to the sides of the barrier. Also as $(\theta_o - \theta_s)$

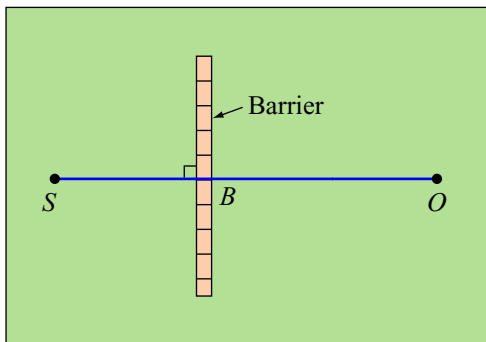
is related to the angle into the shadow, ψ , by

$$\theta_o - \theta_s = -(180 + \psi)$$

the value of M_2 is a function of ψ .

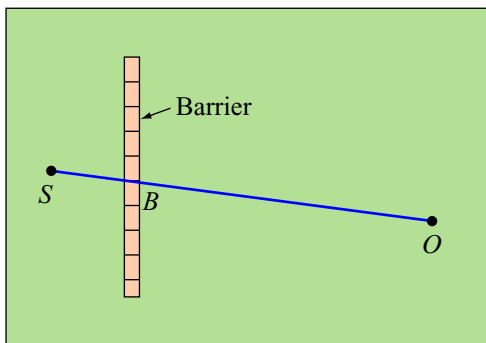
2.3.3 Parameters for maximum noise shielding

The requirements to maximise the shielding by a barrier are listed here. As many of these requirements as possible should be satisfied, within the practical limitations of the noise source and observer locations, in selecting and positioning a barrier.



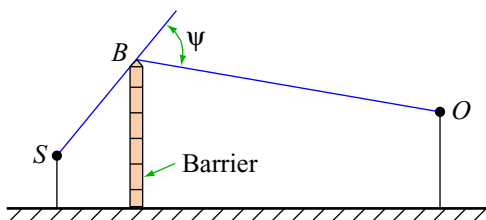
Sketch 2.5a (View on ground plane)

- (a) The barrier should be arranged such that it lies normal to the direct path between the source and observer.



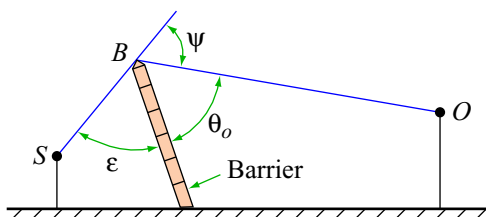
Sketch 2.5b (View on ground plane)

- (b) The barrier should be positioned as close as possible to either the source or observer.



Sketch 2.5c (View normal to barrier)

- (c) The barrier should be made as high as possible since this maximises the angle into the shadow, ψ , at which condition M_2 has its maximum value. For a given barrier height the barrier should be positioned near the lower of the source or observer.



Sketch 2.5d (View normal to barrier)

- (d) The barrier should be orientated such that the difference between θ_o and ϵ is made as small as possible. When $\theta_o = \epsilon = (90 - \psi/2)$ maximum shielding is obtained, and M_1 has its maximum value.